IT and the Economy

In recent years, there has been considerable discussion of the role of information technology in transforming the economy. Terms such as the “digital economy” (Tapscott 1996; U.S. Department of Commerce 1998, 1999a), the “Internet economy” (Center for Research in Electronic Commerce 1999), the “knowledge-based economy” (OECD 1999c), and the “new economy” (Atkinson and Court 1998) have come into common usage. Although these terms have somewhat different meanings, they all suggest that the U.S. economy is transforming in a way that produces higher productivity growth and greater innovation—and that personal computers, high-speed telecommunications, and the Internet are at the heart of this transformation.

Federal Reserve Chairman Alan Greenspan has recently begun to discuss the impact of IT on the economy: “Innovations in information technology—so-called IT—have begun to alter the manner in which we do business and create value, often in ways not readily foreseeable even five years ago” (Greenspan 1999). Greenspan credits information technologies with improving companies’ knowledge of customers’ needs, inventories, and material flows, enabling businesses to remove redundancies. He suggests that IT has also reduced delivery lead-times and streamlined the distribution system.

Large productivity increases and economic transformations, however, have been expected from information technologies for a long time. At least until recently, economists have found little evidence of expected productivity increases or other positive changes from information technology. It is appropriate, therefore, to approach statements about IT-induced transformations of the economy with a degree of caution.

The effect of IT on the economy is a large and complex issue. There are a variety of effects that vary according to the sector of the economy and the organizational and management practices of firms. Moreover, the effects may be rapidly changing as Internet-based electronic commerce expands. This section cannot cover in detail the full range of these issue; it focuses instead on evidence related to five questions:

- ♦ How is IT used in business?
- ♦ What are the effects of IT on productivity and economic growth?
- ♦ How has IT affected the composition of the economy?
- ♦ What are the effects of IT on income and employment?
- ♦ What are the international implications of electronic commerce?

Use of IT in Business

IT is being used in so many ways and in so many kinds of business that it is possible only to sketch that landscape here. At its most basic, IT automates a variety of activities, from control production systems in manufacturing to office-work basics such as word processing and financial calculations. In more sophisticated applications, IT involves databases and information retrieval that assist management, customer service, and logistics and aid product design, marketing, and competitive analysis. IT can combine computing and communications to support ordering and product tracking. These functions are often implemented as mechanization of older processes; ideally, however, they involve fundamental redesign of processes. These functions began using—and in many instances continue to rely on—components such as mainframe, mini-, and microcomputers, as well as telephone networks (the public switched network and leased-line private or virtual private networks). What marks the turn of the century is a move to broader integration of systems and, through them, enterprises. The spread of Internet technology and the proliferation of portable computing and communications devices have accelerated trends that began in past decades and now are hailed as “electronic commerce.”

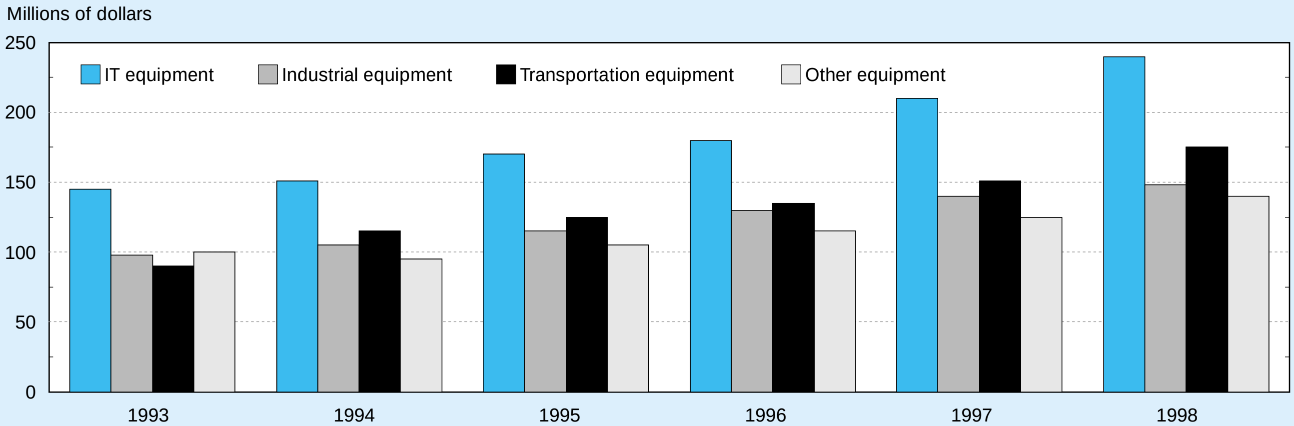
Although IT has the potential to transform business practices, there are substantial costs and barriers to implementation. IT equipment continues to be the largest category of industry spending for all types of capital equipment (including industrial equipment, transportation equipment, and other types of equipment). In current dollars, industry spending on IT equipment rose from $142 billion in 1993 to $233 billion in 1998. (See figure 9-6.)

Using IT in business is expensive not only in terms of initial costs but also in terms of the cost to maintain and upgrade the systems, train the people, and make the organizational changes required to benefit from IT. These costs may greatly exceed the original investment in IT equipment. Organizational changes often are especially difficult. Nevertheless, IT costs of all kinds are regarded as necessary elements for more and more businesses.

Electronic commerce (e-commerce) as a category of business use of IT deserves special attention because of its rapid growth and its potential to affect many business processes. The definition of electronic commerce is a matter of dispute. In one definition of e-commerce, transactions use Internet-based systems, rather than paper or proprietary electronic systems. By this definition, getting money from an ATM is not e-commerce, but transferring funds using the Web is. (See sidebar, “What is Electronic Commerce?”)

E-commerce includes retail and business-to-business commerce. To date, business to business e-commerce has predominated. For example, Forrester Research projects that inter-company Internet commerce will reach $1.3 trillion by 2003 and that online retail trade will reach $184 billion by 2004 (Forrester Research 1998, 1999). In some cases—such as with flowers, books, computers, or industrial parts—the parties use the Internet to make the transaction, but the goods are still delivered physically. In other cases—such as with sales of software, electronic journals, or music—the goods may be delivered electronically. The mix of products made and sold through e-commerce is changing. The rise of electronic trading of securities illustrates the potential for considerable growth of essentially all-electronic business.

Figure 9-6.
Industry spending on IT equipment in the 1990s (current dollars)



SOURCE: U.S. Department of Commerce (1999a), *The Emerging Digital Economy II*, using data from the Bureau of Economic Analysis.

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What is Electronic Commerce?

Definitions of electronic commerce vary. Some definitions include all financial and commercial transactions that take place electronically, including electronic funds transfer (EFT), electronic data interchange (EDI), and credit card activity. These transactions have been going on for years and involve trillions of dollars of funds transfers per day (OECD 1999b). Other definitions limit e-commerce to transactions that take place entirely on open networks such as the Internet. These transactions are still in their infancy.

Definitions also differ in that some groups define e-commerce to include only transactions in which goods or services are ordered and paid for online, whereas other groups include transactions in which goods or services have been ordered, but not paid for, online.

The Organisation for Economic Co-operation and Development (OECD) and its member countries are working to develop standard definitions. OECD (1999b) and the U.S. Department of Commerce (1999a) define e-commerce as business occurring over networks that use nonproprietary protocols that are established through open standard-setting processes such as the Internet. The emphasis on the use of nonproprietary protocols is central. Earlier forms of electronic business, such as EDI and EFT, required preexisting relationships, specialized software, and dedicated communication links. Consequently, such commerce was used mainly to create two-way links between specific parties, such as large businesses and their main suppliers. Commerce over open systems such as the Internet allows communication between diverse computers and communications systems using standard interfaces. These interfaces allow communication among many different customers or suppliers without additional investment, lowering costs and vastly increasing options. This structure has made this form of commerce attractive to many more companies and consumers. Much of the rapidly expanding Internet-based e-commerce, however, is built on experience with earlier (non-Internet) forms of electronic business.

Retail e-commerce has spawned many new businesses that have no physical stores but can deliver a wide variety of goods on request. This mode of operating is often more economical than traditional retail stores. In response, many traditional retail stores have launched their own e-commerce strategies.

Another mode of retail e-commerce that has expanded rapidly is online auctions, which put buyers and sellers directly in touch with each other to negotiate a price. As of September 1999, eBay (one of the first and largest online auction enterprises) offered more than 3 million items for sale in more than 1,500 categories. Hundreds of other online auction enterprises have been established, and many other early e-commerce retailers—such as Amazon.com and Dell Computer—have added auctions as additional features of their Web sites. The mix of distribution channels is changing, and the extent to which new modes replace or complement the old remains to be seen.

Business-to-business e-commerce, like business-to-consumer e-commerce, can enable businesses to offer additional services and improved communication to their customers. Increased communication is enabling firms to outsource more easily, and to streamline and augment supply chain processes. It can also allow businesses to eliminate some intermediary organizations between customer and supplier and give rise to new classes of business intermediaries (such as online auctions). Because business-to-business e-commerce is built on the history of pre-Internet electronic transactions, there is substantial related expertise in place in many companies, and business-to-business e-commerce has expanded rapidly.

Although official nationwide government statistics for e-commerce have not yet been gathered, private studies and market research firms have collected information related to e-commerce. Although these estimates and forecasts do not agree on the definition or value of electronic commerce, they agree that Internet-based commerce is large and growing rapidly. (See text table 9-1.) The wide variation in the estimates reinforces the need for consistent definitions and data collection methods.

The growth of e-commerce has altered much of the discussion of the role of IT in the economy. Previously, much discussion had focused on the application of IT inside companies to improve their internal operations. Electronic commerce is shifting the focus to how businesses are using IT to communicate with customers and suppliers, including new distribution chains and new methods of marketing and selling. Because this arena appears to be changing so quickly, the effects of IT on the economy may change rapidly as well.

International Context of Electronic Commerce

Although the United States has been the world leader in information technology and especially in the Internet, these technologies are expanding rapidly around the globe. Several other countries match or are close to the United States in terms of penetration of personal computers into the home and the office. (See figures 9-7 and 9-8.)

Text table 9-1.
Forecasts of growth in Internet commerce

Study	Date	Result
Forrester Research	12/1998	U.S. inter-company trade of hard goods over the Internet will be $43 billion in 1998; $1.3 trillion in 2003.
University of Texas Center for Research in Electronic Commerce ...	5/1999	Value of 1998 Internet commerce was $102 billion.
International Data Corporation	6/1999	Internet-based worldwide commerce to reach $1 trillion by 2003.

SOURCES: Center for Research in Electronic Commerce (1999), Forrester Research (1998), and International Data Corporation (1999).

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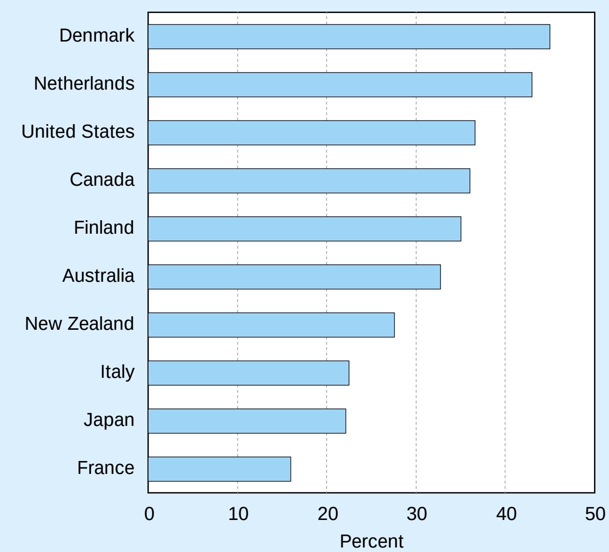
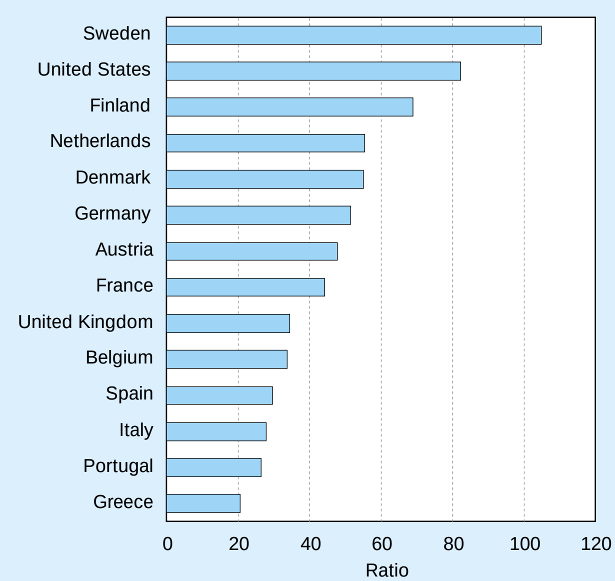
The Scandinavian countries and Canada roughly match the United States in the number of Internet hosts per capita; Finland exceeds the United States in this measure. (See figure 9-9.) Based on the number of secure Web servers (those using encryption and third-party certification, which are suitable for e-commerce) per 100,000 inhabitants, the United States is one of the leading countries in e-commerce, but

Figure 9-7.
PC penetration in households, 1997 or latest year



SOURCE: OECD, compiled from National Statistical Offices, March 1999. *Science & Engineering Indicators – 2000*

Figure 9-8.
PCs per 100 white-collar workers, 1997



SOURCE: OECD, based on ILO and IDC data, March 1999.

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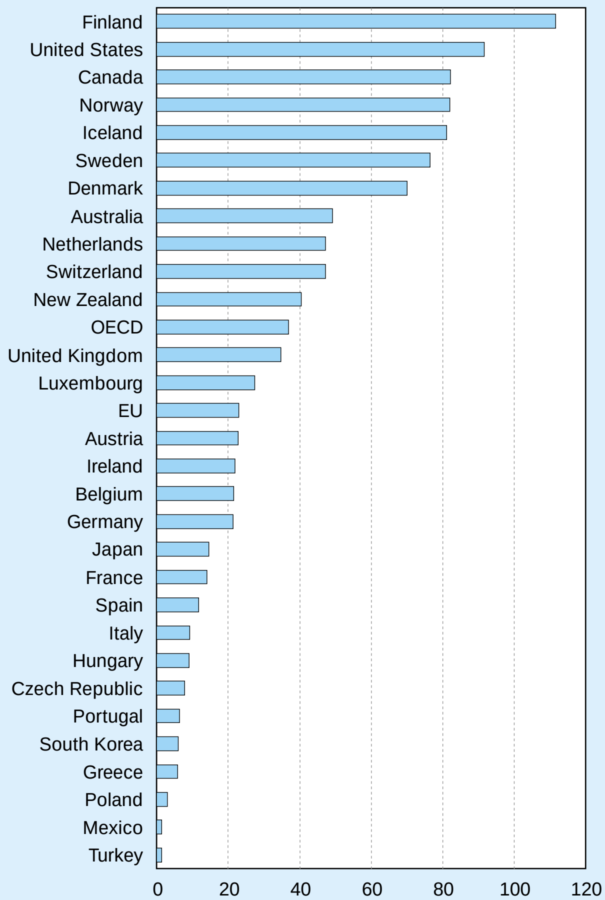
Figure 9-9.
Number of Internet hosts per 1,000 inhabitants: January 1999



SOURCE: Network Wizards and OECD.

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servers suitable for e-commerce are dispersing around the globe. (See figure 9-10.) Countries other than the United States are expected to account for almost half of worldwide Internet commerce by 2003 (IDC 1999).

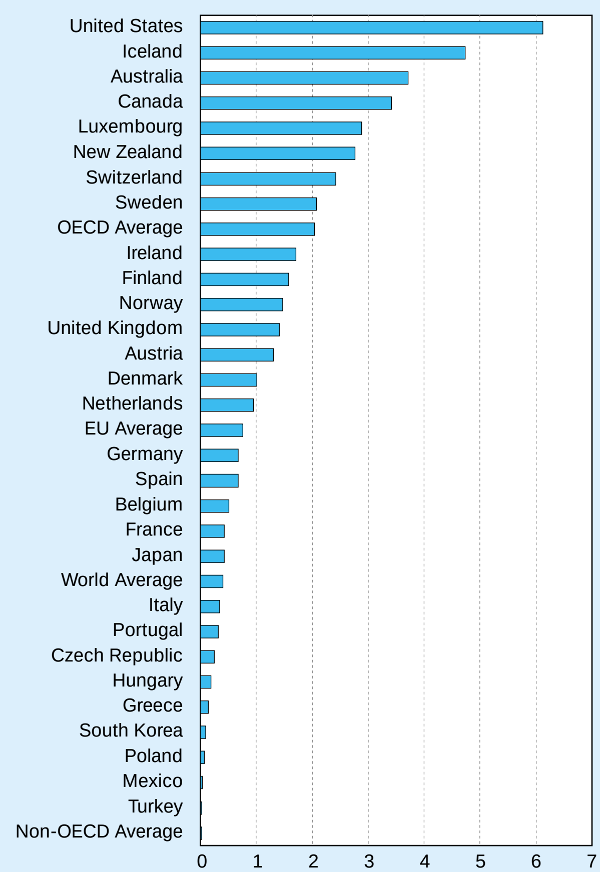
The international diffusion of e-commerce raises many policy issues. On the Internet, information crosses national borders readily, cheaply, and freely. Transactions involving the citizens of one country may fall under the jurisdiction of another country with different laws and regulations governing the transaction. The laws and regulations of many nations frequently come into conflict. For example, trademarks posted in the Internet in one country may violate trademarks in another country. Advertising that is legal in one country may be illegal or objectionable in countries whose residents can view the information on the Web. Collection and use of personal information on Web sites may be legal in one country and illegal in another. International e-commerce may find itself subject to ambiguous or duplicative tax, contract, and intellectual property laws. Although many of these issues have some precedents in the pre-Internet world, they are amplified by the expansion and diffusion of e-commerce. Many small companies without multinational operational or legal experience are increasingly engaged in international markets. E-commerce appears to lower barriers to entry and levels the playing field between large and small companies and large and small countries. E-commerce also appears to be putting pressure on countries around the world to create more harmonized legal environments, working through multinational and nongovernmental organizations.

Effects of IT on Productivity and Economic Growth

Productivity

In spite of the investment in and obvious capabilities of IT, there has been little evidence—until recently—that IT has improved productivity in the aggregate. Solow (1987) termed this inability to find a statistical association between IT investments and productivity in the private sector the "productivity paradox." Many econometric analyses have failed to

Figure 9-10.
Secure Web servers for electronic commerce per 100,000 inhabitants: August 1998



SOURCE: OECD Communications Outlook 1999.

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find any productivity benefits for IT (for reviews of this literature, see Brynjolfsson and Yang 1996 and CSTB 1994a). These studies failed to find a positive and significant contribution of IT to productivity in any sector (neither services nor manufacturing), by any measure (a variety of data sets and methods were used), at any level of analysis (the macroeconomy or specific industries and sectors), or at any time (from the late 1960s to the late 1980s). Positive effects were found only in limited case studies of a single industry or small set of firms.

Brynjolfsson and Hitt (1995, 1996, 1998), however, have found large and significant contributions by IT to productivity using a firm-level database. Every additional dollar of computer capital stock was associated with an increase in marginal output of 81 cents, and every additional dollar spent on IT-related labor was associated with an increase in marginal output of $2.62. Brynjolfsson and Hitt found that although there is a positive correlation between IT and productivity, there is substantial variation between firms. Firm-level variables can account for half of the variation in IT's contribution to marginal productivity. This finding suggests that the effectiveness of IT depends on how a firm uses it. Brynjolfsson and Hitt (1998) conclude that although computerization does not automatically increase productivity, it is an essential component of a broader system of organizational change that does.

Several factors may explain the contrast between the findings of Brynjolfsson and Hitt and the earlier productivity studies. The later time period of their study (1987–91); the use of a larger data set; more detailed, firm-level data; and the inclusion of IT-related labor may all be reasons why their findings are more positive than those resulting from earlier research. Using similar data and methods, other analysts have also found significant positive rates of return at the firm level, including Lichtenberg (1995) and Link and Scott (1998).

Oliner and Sichel (1994) found that from 1970 to 1992, computer hardware contributed 0.15 percentage points to the total U.S. output growth rate of 2.8 percent. When software and computer-related labor are included, this contribution doubles to 0.31 percentage points for the period 1987–93 (11 percent of total growth). Other capital and labor inputs, as well as multifactor productivity gains, account for about 90 percent of the growth in U.S. output during this period. Oliner and Sichel note that computing-related inputs are a very small portion of total capital and labor and have only recently grown large enough to have a measurable impact. They conclude that "computing equipment can be productive at the firm level and yet make little contribution to aggregate growth, precisely because computers remain a relatively minor factor of production" (Oliner and Sichel 1994, 286).

More recently, the U.S. Department of Commerce has examined the gross product originating—or value added—per worker (GPO/W) as a measure of productivity (U.S. Department of Commerce 1999a). Nonfarm industries were divided into IT-producing, IT-using, and non–IT-intensive and then further divided into goods and services industries. IT-producing industries have experienced strong growth in GPO/W; in contrast, IT-using industries, especially in the services, have experienced slight GPO/W shrinkage. (See text table 9-2.)

Although growth in GPO/W was greater for IT-using industries than for non–IT-intensive industries in the goods producing sector, it was less for IT-using industries than for non–IT-intensive industries in the services sector.

There are two common explanations for the productivity paradox. First, there are measurement problems. As Brynjolfsson and Hitt (1998) observe, two aspects of productivity have increasingly defied precise measurement: output and input. The measurement problems are substantial (Baily and Chakrabarti 1988; Brynjolfsson 1993; CSTB 1994a; Griliches 1997; Oliner and Sichel 1994).

Regarding inputs, there are issues about what constitutes IT. Is it capital investments only, or does it include labor (which represents the bulk of IT operating costs)? Do IT capital investments include more than computers and software, and if so, what? Choices about what to count as an IT equipment expense include computing hardware and software, communications equipment, and a variety of office machines (such as photocopiers and some instruments). This choice is further complicated by the fact that IT is increasingly embedded in other systems, such as machine tools, automobiles, and appliances. At present, there is little consistency among studies, and sources of IT investment data vary from aggregate government data to private survey-based firm data.

Another measurement issue is how to assign dollar values to IT as a factor input. IT can be measured as a flow (annual expenses or purchases) or as a stock (the cumulation of equipment over time). In both instances, price deflators are required to compare stocks or flows over time by converting them to "real" dollars. IT equipment is especially problematic for establishing reliable deflators. For example, not only has the sales price of computing equipment been falling rapidly, but because quality has increased exponentially, existing computing stock becomes obsolete very quickly and therefore is difficult to evaluate adequately.

The pace of technological change in IT greatly complicates analysts' abilities to construct quality-adjusted price deflators and appropriate depreciation rates. The Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS) have developed price indices that reflect changes in IT quality. The values used significantly affect research outcomes by influencing the value of expenses and stocks in different periods.

A third measurement difficulty relates to how to measure the output of information processing. IT is used extensively for activities that do not result in tangible market outputs (e.g., accounting, scheduling, reporting). Consequently, it is difficult to assign a dollar value to the output of IT—a measurement that is essential for accurate productivity analysis. This measurement challenge is exacerbated in the services sector, where output measures must also capture qualitative differences in services (Mark 1982, Noyelle 1990). Services are hard to measure; according to Department of Commerce classification, almost 90 percent of the nonfarm U.S. economy

Text table 9-2.
Gross product originating per worker, annual growth rate: 1990–97

Gross product	Annual growth rate (1990–97)
Total private nonfarm	1.4
IT-producing	10.4
Goods	23.9
Services	5.8
IT-using	-0.1
Goods	2.4
Services	-0.3
Non-IT intensive	1.1
Goods	1.3
Services	1.3
All industries other than IT-producing	0.5

SOURCE: U.S. Department of Commerce, *The Emerging Digital Economy II.* (Washington, DC: 1999). Available from <<http://www.ecommerce.gov>>.

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that is IT-using is in the service sector.[2] (See text table 9-3.)

A fourth measurement issue concerns how to value IT benefits that do not show up as classical efficiency gains, such as qualitative improvements in customer service. These benefits might include enhanced timeliness, performance, functionality, flexibility, accuracy, precision, customization, cycle times, variety, and responsiveness (Bradley, Hausman, and Nolan 1993; Byrne 1996; CSTB 1994a). These qualitative dimensions are much more likely to show up as downstream benefits to the consumer (Bresnahan 1986) or as greater competitiveness for a firm (Baily and Chakrabarti 1988; Banker and Kauffman 1988; Brynjolfsson 1993; Porter and Millar 1985).

Another explanation of the productivity paradox is that it is a real but temporary phenomenon. Sociologists and economic historians have long argued that society's ability to fully exploit a new technology lags—often by decades—introduction of the technology itself (Ogburn 1964, Perez 1983). Similarly, in organizational change scholarship, institutional resistance to change is the norm. David (1989) found, for example, that nearly 20 years elapsed before the electric generator—an invention comparable to IT in scope and consequence—had a measurable effect on industrial productivity. With respect to IT specifically, firm-level performance can vary considerably, and the effective use of IT is apparently contingent on moderating variables at the organizational level—including strategy, leadership, attitudes, organizational structure, appropriate task and process reengineering, individual and organizational learning, and managerial style and decisionmaking (Allen and Morton 1994; Banker, Kauffman, and Mahmood 1993; Cron and Sobol 1983; Curley and Pyburn 1982; Danziger and Kraemer 1986; Graham 1976; Khosrowpour 1994; Landauer 1995; Tapscott 1996; Thurow 1987).

[2]Agriculture can also be IT-intensive.

The banking and trucking industries are two very different sectors that illustrate some of the effects—and some of the difficulties in measuring those effects—of IT in specific sectors. (See sidebars, "IT and the Banking Industry" and "IT and the Trucking Industry.") The banking industry is a white-collar service industry that has long been at the forefront of IT use. The trucking industry is a predominately blue-collar industry that has not been considered IT-intensive. IT has strong but difficult to measure effects on productivity and work in both of these industries.

Effects on Inflation and Growth

IT appears to be having positive effects on inflation and growth in the economy as a whole. These effects relate primarily to growth and declining prices in the IT sector rather than the effects of application of IT.

The U.S. Department of Commerce (1999a) found that declining prices in IT-producing industries have helped to reduce inflation in the economy as a whole. (See text table 9-4.) Decreasing IT costs may also have helped other industries control their costs. The department also found that IT-producing industries have contributed substantially to economic growth in the United States. The department estimates that over the past four years, IT industries have contributed more than one-third of the growth of real output for the overall economy. (See text table 9-5.)

Effects on Composition of the Economy

In addition to causing changes in the overall economy, IT is causing changes in the structure of the economy. One obvious change is growth in the IT-producing sector. Because that sector has been growing faster than the economy as a whole, its share of the economy has increased. (See figure 9-12.)

IT also is commonly credited as a key factor in the structural shift from manufacturing to services in the U.S. economy. Growth in existing services such as banking and the creation of new industries such as software engineering are attributed to the widespread diffusion of IT (CSTB 1994a, Link and Scott 1998). From 1959 to 1997, the service sector grew from 49 percent of U.S. gross domestic product (GDP) to 64 per-

Text table 9-3.
Percentage share of total private nonfarm gross product originating by sector, United States: 1990–97

Sector	Goods	Services	Total
IT-producing	2.0	6.2	8.2
IT-using	5.0	43.3	48.3
Non-IT intensive	23.0	20.6	43.6
Total	30.0	70.0	100.0

SOURCE: U.S. Department of Commerce, *The Emerging Digital Economy II.* (Washington, DC: 1999). Available from <<http://www.ecommerce.gov>>.

See appendix table 9-3. *Science & Engineering Indicators – 2000* cent of GDP, while manufacturing declined from 28 percent of GDP to 17 percent of GDP.

The expansion of the service sector has been driven by industries that are often classified as "knowledge" industries (see Machlup 1962)—finance, insurance, and real estate (FIRE)—as well as professional services such as health and education. The share of GDP accounted for by wholesale and retail trade declined from 1959 to 1997, while personal services and transportation and utilities remained essentially unchanged. (See appendix table 9-4.) In contrast, FIRE's share of GDP grew by 5.8 percentage points, and that of professional services increased by 7.7 percentage points.

IT and the Banking Industry

The banking industry reflects most of the empirical dilemmas associated with measuring the impacts of IT: heavy investment in IT; little measurable improvement in productivity traced to IT; and effects that reflect quality improvements, rapid product diversification, and substantial growth in volume of commercial transactions. IT has changed the structure and service quality of banking and appears to have a positive effect on cost reduction. It has taken decades to achieve these results, however, and traditional productivity analyses still do not detect positive associations between IT investments and productivity in the commercial banking sector.

Banking industry investments in IT increased substantially from the late 1960s to the late 1980s. Annual investments in IT (in constant 1982 dollars) grew from $0.1 billion in 1969 to $1.6 billion in 1980 to $13.8 billion in 1989 (CTSB 1994a). By 1989, the banking industry was investing more funds in IT annually than all of the other major service industries except telecommunications.

IT applications in banking included accounts management and check processing via magnetic ink character recognition. Automated clearinghouses, which enabled electronic funds transfer (EFT), were introduced in the early 1970s, and ATMs were introduced in the late 1970s. EFT, ATMs, and telephone transaction capabilities have replaced a wide variety of paper and in-person transactions in banking, including account deposits and withdrawals, accounts management, credit applications and approvals, cash dispensing, funds transfers, point-of-sale transactions, credit card payments, and consolidation of banking operations.

Major cross-sector studies (see Brynjolfsson and Yang 1996 for reviews), however, failed to detect positive productivity returns for IT in the banking industry, and Franke's (1989) study of the financial sector (insurance and banking combined) suggested that IT is associated with negative productivity effects. On the other hand, labor productivity has been steadily improving in the banking industry. Productivity improved substantially from 1982 through 1997. The difficulty is in empirically linking these improvements to investment in IT.

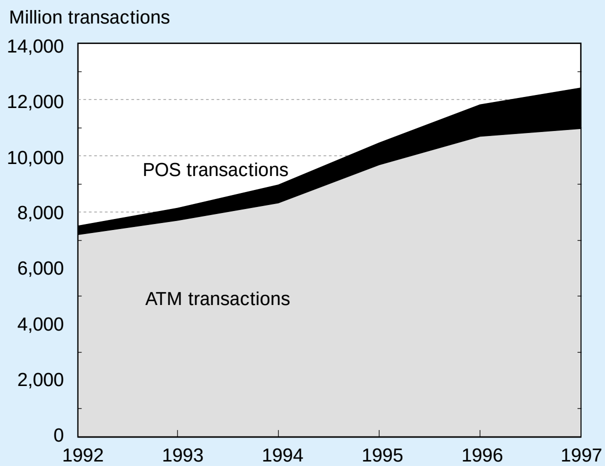
IT-related productivity growth may have been slow because of problems with early generations of information technologies and organizational adaptation. The National Research Council reported that early applications of IT were costly and cumbersome; software and equipment had to be updated and replaced frequently, and IT systems required large amounts of tailoring, training, upgrading, and updating. Cost control, management skills, and productivity tracking systems lagged the new technologies in a rapidly changing, competitive marketplace (CSTB 1994a, 80–81).

In addition, many of the benefits of IT were in areas that productivity indicators did not capture. These benefits included expansion of banking products and services, time and cost savings, and competitive positioning. Banking products and services have proliferated with the use of EFT, ATMs, telephone transactions, and automated credit and loan procedures. Banks thus process billions of transactions a year—including clearing individual checks, ATM cash dispersal, account inquiries, and loan approvals—a volume of interactions that would not be possible without automation. For example, automated clearing house payments, which include direct deposit of payroll payments, expense reimbursements, government benefits and tax refunds, and direct payments of bills, totaled more that 5.3 billion payments worth $16.4 trillion in 1998 (National Automated Clearing House Association 1999). The number of electronic cash transactions and payments for goods and services was more than 12 billion in 1997, compared with 7.5 billion in 1992. (See figure 9-11.)

Bresnahan (1986) estimates that the benefits to consumers from the use of mainframe computers for financial services were five times greater than the investments in the computers themselves. Qualitative improvement in customer convenience, ease, and scope of access to financial resources is reflected in the overall growth of electronic transactions. Time and cost savings for the industry are also notable. The processing time for credit card authorizations has shrunk dramatically, and banks have been able to reduce their staffs while increasing the number of transactions (CSTB 1994a, 83–84). ATM transactions cost an estimated 27 cents, compared to $1.07 for a human teller transaction; automated telephone transactions cost about $0.35, compared to $1.82 for a phone call processed by bank personnel (Morisi 1996). In a study of 759 banks, Alpar and Kim (1991) found that a 10 percent increase in IT expenses led to a 1.9 percent decrease in total bank costs.

Although productivity measures do not find a link between banking industry output and IT investments, it is important to note that while the volume of financial transactions has been increasing at a dramatic rate, employment in the sector has been falling. By 1996, employment in the commercial banking industry was 100,000 employees below its historic peak in 1990.

Figure 9-11.
U.S. electronic funds transfer volume



NOTES: Electronic funds transfer includes automated teller machine (ATM) transactions and transactions at point-of-sale (POS) terminals. POS terminals are electronic terminals in retail stores that allow a customer to pay for goods through a direct debit to a customer's account at the bank.

SOURCE: Statistical Abstract of the United States, table 825. Data from: Faulkner & Gray, Chicago, IL, Faulkner & Gray/EFT Network Data Book-1998. September 26, 1997 (copyright).

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IT has not been empirically linked in a definitive way to the expansion of the service sector, however. In a detailed study of several key service industries (banking, insurance, air transport, and telecommunications), the National Research Council concluded that although the benefits of IT for individual industries could be qualitatively described, IT could not be causally linked to gross product output of the individual industry for methodological reasons (CSTB 1994a). Expansion of the air transport, banking, finance, and trade industries probably would not have been as great in the absence of IT (CSTB 1994a). Moreover, IT is particularly concentrated in service industries that have experienced rapid expansion.

IT may also be contributing to other shifts in the economy. Home based e-commerce may be displacing traditional banking, travel, legal, and educational services to some extent. To the extent that home-based IT replaces services that previously were paid for and captured in economic indicators, this effect may lead to an understatement of economic growth. To date, home users have been disproportionately persons with higher income and more education (see chapter 8, "Science and Technology: Public Attitudes and Public Understanding" and "IT and the Citizen" in this chapter). If that pattern persists, the distribution of real income, including nonmarket production, may become less equitable. Understanding the distribution of work between the household and the market may once again emerge as a critical element in understanding economic growth.

IT and the Trucking Industry*

Transportation is an important sector of the U.S. economy. Nearly 75 percent of all freight is transported by truck at some point in the distribution chain. Many changes have occurred in the industry over the past 15 years—reflecting deregulation, increased fuel efficiency, and increased sizes of trucks. More recent changes have related to the use of IT, including scheduling, dispatching, and onboard communications systems (such as cellular phones and computers).

Existing evidence suggests a substantial boost in productivity from rather modest investments in IT—particularly from more effective routing and scheduling, such as with "just-in-time" delivery systems. This productivity increase is important because trucking is not one of the industries that shows up as substantially dependent on IT. Trucking is not considered an IT-dependent industry in terms of IT expenditures as a share of capital costs or IT per worker. Yet with input from sources external to the industry, IT appears to play a significant role in trucking.

Approaches to the use of IT are heterogeneous at the firm level. Some trucking firms have been innovative leaders, others distant followers; still other firms have been operating in crisis mode to catch up to the rest of the fleet. Investment in IT may not correlate directly to productivity because the innovative leaders and firms acting in crisis mode may spend more—but less cost-effectively—on IT than the distant followers. The lack of training of the workforce and limited IT training of managers seems not to be fatal in the adoption of IT. Many workers make only passive use of the technology. Rising productivity may benefit company earnings and consumers more than it benefits drivers, who do not appear to receive pay increases that reflect their increased productivity. IT benefits also may accrue to those who develop and implement the dispatching software systems, rather than to drivers.

*The information in this box is based on the work of the University of Michigan Trucking Industry Program (UMTIP). See Belman et al. (1998) and Nagarajan et al. (1999).

Effects on Income and Employment

Information technology creates some new jobs and eliminates others. As jobs are created or eliminated, the labor markets adjust in complex ways. Wages go up in areas where the demand for skills exceeds the supply and go down in areas where there are more jobs than workers. Over time, the effects of IT are likely to appear not in unemployment figures but in the wages of different occupations.

In a review of the literature on computerization and wages, Katz (1999) notes that many authors have found that wage inequities and educational wage differentials have increased in the United States in the past two decades—coinciding with

Text table 9-4.
Price changes, IT-producing and all other industries

	1993	1994	1995	1996	1997
IT-producing industries	–2.4	–2.6	–4.9	–7.0	–7.5
Rest of the economy	3.0	2.7	2.8	2.6	2.6
GDP	2.6	2.4	2.3	1.9	1.9

SOURCE: U.S. Department of Commerce, *The Emerging Digital Workforce II.* (Washington, DC: 1999). Available from <<http://www.ecommerce.gov>>. Based on BEA and Census data.

See appendix table 9-3.

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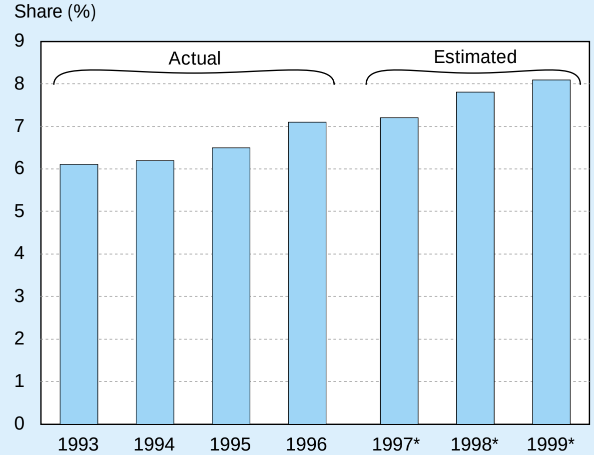
Figure 9-12.
IT-producing industries' share of the economy: 1993–99



SOURCES: U.S. Department of Commerce, *The Emerging Digital Economy II* (Washington, DC: 1999). Available from <<http://www.ecommerce.gov>>. ESA estimates derived from BEA and Census data for 1993–1996. ESA estimates for 1997-1999 derived using DOC's "Industry and Trade Outook."

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the computerization of the workplace. From 1973 to 1995, wages have increased in the top 30 percentiles and have decreased in the bottom 70. (See appendix table 9-10.) Rising wages and labor income of educated workers, combined with rising relative supply, are consistent with a model in which IT allows skilled workers to produce things previously in the domain of the less-skilled. This trend deteriorates the terms of trade of the less skilled workers, reducing their relative income (Gomery 1994, Johnson and Stafford 1998).

Katz (1999) notes that relative employment and wages have both increased within industries for more educated workers during the 1980s and 1990s, indicating shifts favoring more skilled workers. He finds that skill-based and organizational changes that have accompanied the computer revolution appear to have contributed to faster growth in the demand for skilled labor starting in the 1970s. Factors other than technological change—including the slowdown in the increase of college-educated people entering the labor force, globalization (especially outsourcing of low-skilled work), and the weakening of unions—may also play a role in creating rising wage inequities, however.

Although evidence suggests that IT should increase the demand for workers who manipulate and analyze information relative to the demand for non-knowledge workers or those who simply enter and collate data, there is also a popular fear that automation will reduce the demands on an individual's conceptual talents and facility with machinery, equipment, and tools. Individual case studies of specific industries, occupations, and information technologies illustrate that IT can sometimes reduce and sometimes increase the skills required in particular jobs (for reviews, see Attewell and Rule 1994, Cyert and Mowery 1987).

On balance, however, several studies—using different data sets and methodologies—suggest that no overall lessening of skills is occurring in the workforce and that upgrading may be widespread. For example, Castells (1996) finds that em-

Text table 9-5.
IT-producing industries: contribution to real economic growth

	1993	1994	1995	1996	1997 est.	1998 est.
(1) Change in real gross domestic income* (GDI)	2.2	4.1	2.9	3.5	4.2	4.1
Percentage points						
(2) IT contribution	0.6	0.6	1.2	1.5	1.2	1.2
(3) All other industries	1.6	3.5	1.7	2.0	3.0	2.9
(4) IT portion (percent) of GDI change (2)÷(1)	26.0	15.0	41.0	42.0	28.0	29.0

*GDI is equal to the income that originates in the production of goods and services attributable to labor and property located in the United States.

SOURCE: U.S. Department of Commerce (1999) from ESA estimates derived from BEA and Census data for 1993–96. ESA estimates for 1997–98 derived from DOC's "Industry and Trade Outlook '99."

See appendix table 9-3.

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ployment in managerial, professional, and technical classes has been expanding at a faster rate than employment in non- and semi-skilled occupations. Howell and Wolff (1993) reach much the same conclusion; using detailed data on cognitive and motor skills required for specific occupations from 1959 to 1990, they found that skill restructuring (principally upgrading) in the labor force began in the 1970s and continued in the 1980s in patterns that are "broadly consistent with what one might expect from the rapid expansion of new [information] technology" (Howell and Wolff 1993, 12). Howell and Wolff also found that demand for the most cognitively skilled information occupations grew more rapidly than demand for other occupations during some periods. Analyzing data from the Annual Survey of Manufacturers, Berman, Bound, and Griliches (1994) document significant skill upgrading throughout the manufacturing sector during the 1980s—which they attribute in part to computerization of the workplace. Their findings indicate a distinct shift in the demand for labor in the United States from less skilled to more highly (cognitively) skilled labor—a shift that has been linked theoretically and empirically to the diffusion of IT. Autor, Katz, and Krueger (1997) found that those industries that experienced the largest growth in computer use also tended to shift their employee mix from administrative and support workers toward managers and professionals (a finding consistent with Castells 1996).

In addition to the effects of IT on wages, Katz (1999) identifies several other issues relating to IT and employment that merit further study. For example, how does the growth of the Internet affect the geographic distribution of work among large cities, smaller cities, suburban areas, and rural areas? What is the promise of telecommuting, and what is the reality? What are the sources of employee training in the rapidly changing digital economy? How do Internet job searching and computer-oriented labor market intermediaries (e.g., the temporary help industry) affect the labor market? These topics suggest a rich area for further study.

IT Workforce

With rapid expansion of IT development and application, and with the overall U.S. economy running at full employment, it is not surprising that there have been recent concerns about the availability of IT workers. Demand for IT workers has been growing steadily for years. (See figure 9-13.)

The IT industry itself has asserted that there is a serious shortage of IT workers. The U.S. Department of Commerce (1997, 1999b) published Bureau of Labor Statistics projections on future U.S. demand for three core occupational classifications of IT workers—computer scientists and engineers, systems analysts, and computer programmers. These projections indicated that between 1996 and 2006, the United States would require more than 1.3 million new IT workers in these three occupations. (See text table 9-6.)

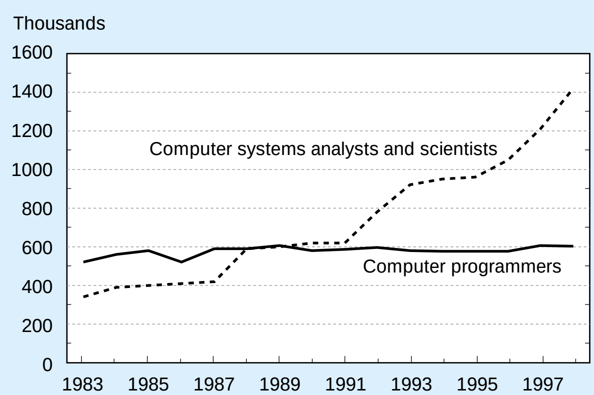
After increasing sharply in the early 1980s, the number of computer science degrees awarded declined sharply after 1986 and has been flat for the past few years. (See chapter 4, "Higher Education in Science and Engineering.")

The assertion that there is a shortage of IT workers has been contentious. Although many people in industry believe that they need more IT-trained workers to meet the growing demand, some employee groups believe that there are enough trained technical professionals in the United States—but that industry has not tapped these existing labor pools (especially older engineers). The debate has been especially polarized over the issue of whether to allow more foreign technically trained workers to enter the country on temporary H-1B visas.

Other studies have examined the IT workforce issue (Freeman and Aspray 1999, Johnson and Bobo 1998, Lerman 1998, U.S. Department of Commerce 1999b; see also chapter 3, "Science and Engineering Workforce"). These studies have generally concluded that:

- The IT labor market appears to be tight (to a somewhat greater extent than the overall job market), but existing data cannot prove or disprove that there is a shortage. Federal data are limited by untimely reporting, out-of-date occupational descriptions, and incompatibilities between supply and demand data collected by different agencies.
- The IT labor market is not homogeneous. Supply and demand characteristics vary by region, by industry segment, and by specific skills. Because product cycle times are very fast in much of the IT industry, a premium is paid for people with specific current skills rather than people who require training to be effective. Competition is especially intense for people with specific "hot" skills in specific markets.
- People enter IT careers from a variety of directions. IT workers include people who majored in IT-related disciplines at the associate, bachelor's, master's, and doctoral

Figure 9-13.
Employment in core IT occupations: 1983–98



SOURCE: U.S. Department of Commerce, *The Digital Workforce: Building Infotech Skills at the Speed of Innovation* (Washington, DC: 1999). Available from <<http://www.ta.doc.gov/reports/itsw/digital.pdf>>.

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Text table 9-6.
Employment projections for core IT occupations
(Thousands)

Occupation	Employment 1996	Employment 2006	Change, 1996-2006 Number	Change, 1996-2006 Percentage	Net Replacements	Total Job Openings (growth and net replacement)
Computer scientists	212	461	249	118	19	268
Computer engineers	216	451	235	109	15	250
Systems analysts	506	1,025	520	103	34	554
Computer programmers	568	697	129	23	177	306
Total	1,502	2,634	1,133	75	245	1,378

SOURCE: U.S. Department of Commerce, *The Digital Work Force: Building Infotech Skills at the Speed of Innovation.* (Washington, DC: 1999); and U.S. Department of Labor Statistics, 1996 industry-occupation employment matrix.

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levels; people from other science, engineering, and business fields; and people from nontechnical disciplines who have taken some courses in IT subjects. Many people also enter the field through continuing education programs and for-profit schools. New modes of instruction delivery, such as distance learning are being used. (See "Distance Education.")

- The job market is showing signs of responding—if imperfectly—to the tight IT labor markets. Wage increases are attracting more people to the field. A large number of initiatives around the country have been started to address the problem. Enrollments are increasing in training programs and in 4-year degree programs.

IT and Education

Information technologies are likely to have a substantial effect on the entire spectrum of education by affecting how we learn, what we know, and where we obtain knowledge and information. IT influences the creation of scientifically derived knowledge; how children learn in schools; lifelong learning by adults; and the storage of a society's cumulative knowledge, history, and culture. IT can bring new information and types of instruction into the classroom; it can provide students with new tools for finding and manipulating information; and it can provide resources that are not available in a particular geographical area. At the same time, IT may impose new costs in equipment, software, and the time it takes to learn new systems; it also threatens to disrupt existing methods of knowledge creation and transfer, as well as the archiving of knowledge.

This section reviews the role of IT in classrooms, in distance education, in the storage and dissemination of knowledge, and in the creation of new knowledge. In each of these areas, similar technologies can be applied from K–12 education to leading-edge research. Much of the attention in each of these categories, however, is directed at one level. Most discussion of IT in the classroom, for example, focuses on K–12 education. Distance education is being used most in higher education. Discussion of the creation, storage, and dissemination of knowledge focuses on the research community. Although this discussion concentrates on these areas, virtually all of the technologies discussed here can be used—and are being used—at many levels in the education/research system. Other chapters of this report discuss the use of information technology in specific parts of the education system: For example, chapter 5 discusses IT at the K–12 level.

IT in the Classroom

In recent years there has been a great deal of emphasis in the United States on increasing the use of information technologies in U.S. elementary and secondary schools (Children's Partnership 1996, McKinsey and Company 1995, NIIAC 1995, PCAST 1997). Greater use of IT at the precollege level is frequently regarded as providing the training students need to be competent members of the information society and to enjoy the benefits of information technology. Schools are expected to expose all children to information technologies so society does not become stratified into information-rich and information-poor classes. A 1992 survey of elementary and high school principals found that the three main reasons schools adopt computer technologies are to give students the experience they will need with computers for the future, to keep the curriculum and teaching methods current, and to improve student achievement (Pelgrum, Janssen, and Plomp 1993).

Assumptions about the educational benefits of IT are not universal, however. *Silicon Snake Oil: Second Thoughts on the Information Highway* (Stoll 1995) represents one critique of claims about the social payoff of IT (including educational benefits). Scholar Larry Cuban (1994) has questioned the use of computers in classrooms, and journalist Todd Oppenheimer (1997) has described the opportunity costs of spending educational funds on IT.

The fundamental dilemma of IT-based education is that it has not been proven to be more cost-effective than other forms of instruction (Cuban 1994, Kulik and Kulik 1991, Rosenberg